

WHAT IS CLAIMED IS:

1. A chimeric polypeptide comprising at least a first domain comprising a cannulae polypeptide and at least a second domain comprising a heterologous polypeptide or peptide, carbohydrate, small molecule, nucleic acid or lipid.

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2. The chimeric polypeptide of claim 1, wherein the heterologous polypeptide or peptide is inserted at the amino terminal end, the carboxy terminal end or internal to the cannulae polypeptide.

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3. The chimeric polypeptide of claim 1, wherein the cannulae polypeptide comprises a protein having at least about 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% sequence identity to SEQ ID NO:2, SEQ ID NO:4, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10 or SEQ ID NO:12.

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4. The chimeric polypeptide of claim 1, wherein the chimeric polypeptide is capable of assembling into a polymer.

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5. The chimeric polypeptide of claim 4, wherein polymer acts as a biosynthetic pathway or a selection scaffolding

6. The chimeric polypeptide of claim 1, wherein the chimeric polypeptide is capable of acting as a chiral selector.

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7. The chimeric polypeptide of claim 3, wherein the cannulae polypeptide comprises a protein having sequence as set forth in SEQ ID NO:2 SEQ ID NO:4, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10 or SEQ ID NO:12, or, a FtsZ domain.

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8. The chimeric polypeptide of claim 1, wherein the cannulae polypeptide is capable of assembling into a polymer.

9. The chimeric polypeptide of claim 1, wherein the cannulae polypeptide or the chimeric polypeptide is capable of assembling into a structure having an interior space.

5 10. The chimeric polypeptide of claim 9, wherein the structure having an interior space comprises a tubule or a nanotubule.

11. The chimeric polypeptide of claim 10, wherein the heterologous polypeptide or peptide is exposed into the inner lumen of the tubule or nanotubule.

10 12. The chimeric polypeptide of claim 10, wherein the heterologous polypeptide or peptide is expressed on the exterior of the tubule or nanotubule.

13. The chimeric polypeptide of claim 1, wherein the heterologous polypeptide or peptide comprises a chiral selection motif.

14. The chimeric polypeptide of claim 1, wherein the heterologous polypeptide or peptide comprises a receptor, a binding protein or a ligand.

20 15. The chimeric polypeptide of claim 14, wherein the binding protein comprises biotin.

16. The chimeric polypeptide of claim 1, wherein the heterologous polypeptide or peptide comprises an enzyme.

25 17. The chimeric polypeptide of claim 16, wherein the heterologous polypeptide or peptide comprises an enzyme active site.

18. The chimeric polypeptide of claim 1, wherein the heterologous polypeptide or peptide comprises an antigen or an antigen binding site.

30 19. The chimeric polypeptide of claim 1, wherein the heterologous polypeptide or peptide comprises a green fluorescent protein, an alpha-galactosidase or a chloramphenicol acetyltransferase.

20. The chimeric polypeptide of claim 1, wherein the chimeric polypeptide is a recombinant protein.

5 21. The chimeric polypeptide of claim 1, wherein at least one subsequence of the cannulae polypeptide has been removed.

22. The chimeric polypeptide of claim 21, wherein the heterologous polypeptide or peptide is inserted into the cannulae polypeptide at the site the
10 subsequence was removed.

23. The chimeric polypeptide of claim 22, wherein the cannulae polypeptide is a CanA polypeptide and the removed subsequence is a 14 residue motif consisting of residue 123 to residue 136 of SEQ ID NO:2 (PDKTG YTN TSIWVP), or, a
15 17 residue motif located at amino acid residue 123 to residue 139 of SEQ ID NO:2 (PDKTG YTN TSIWVP GEP).

24. The chimeric polypeptide of claim 1, wherein the heterologous polypeptide or peptide is inserted into the CanA polypeptide at the site a subsequence is
20 removed.

25. The chimeric polypeptide of claim 24, wherein the heterologous polypeptide or peptide is a 14 or a 17 residue motif inserted into the CanA polypeptide to replace a removed 14 or a 17 residue motif.

26. An immobilized chimeric polypeptide comprising the chimeric polypeptide of claim 1.

27. A tubule or nanotubule, bundle, ball, fiber, filament or sheet
30 comprising a plurality of chimeric polypeptides as set forth in claim 1.

28. The tubule or nanotubule, bundle, ball, fiber, filament or sheet of claim 27, wherein the heterologous polypeptide or peptide comprises an enzyme or an enzyme co-factor.

29. The tubule or nanotubule, bundle, ball, fiber, filament or sheet of claim 28, wherein the tubule or nanotubule, bundle, ball, fiber, filament or sheet comprises a plurality of different enzymes.

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30. The tubule or nanotubule, bundle, ball, fiber, filament or sheet of claim 29, wherein the plurality of enzymes comprises a biosynthetic pathway.

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31. The tubule or nanotubule, bundle, ball, fiber, filament or sheet of claim 31, wherein the plurality of enzymes are arranged along the length of the tubule or nanotubule, bundle, ball, fiber, filament or sheet in the same order as they act in the biosynthetic pathway.

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32. The tubule or nanotubule, bundle, ball, fiber, filament or sheet of claim 27, wherein the heterologous polypeptide or peptide comprises a chiral selection motif.

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33. The tubule or nanotubule, bundle, ball, fiber, filament or sheet of claim 27, wherein the heterologous polypeptide or peptide comprises a protein binding domain or small molecule binding domain.

34. The tubule or nanotubule, bundle, ball, fiber, filament or sheet of claim 33, wherein the protein binding domain comprises biotin.

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35. A nucleic acid comprising a sequence encoding the chimeric polypeptide of claim 1.

36. An expression cassette comprising the nucleic acid of claim 35.

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37. A cell comprising the nucleic acid of claim 35.

38. The cell of claim 37, wherein the cell is a bacterial cell, a plant cell, a yeast cell, a fungal cell, an insect cell or a mammalian cell.

39. A transgenic non-human animal comprising the nucleic acid of claim 35.

40. A plant or a seed comprising the nucleic acid of claim 35 or the chimeric polypeptide of claim 1.

41. A method for the chiral selection of a composition, comprising the following steps:

- (a) providing a chimeric polypeptide as set forth in claim 6;
- (b) providing a racemic mixture of the composition; and,
- (c) contacting the racemic mixture with the chimeric polypeptide under conditions wherein only one enantiomer of the composition binds to the chimeric polypeptide; thereby selecting a single chiral specie of the racemic mixture.

42. A method for the chiral selection of a composition, comprising the following steps:

- (a) providing a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27;
- (b) providing a racemic mixture of the composition; and,
- (c) contacting the racemic mixture with the tubule or nanotubule, bundle, ball, fiber, filament or sheet under conditions wherein only one enantiomer of the composition binds to the tubule or nanotubule, bundle, ball, fiber, filament or sheet; thereby selecting a single chiral specie of the racemic mixture.

43. A method for enzymatic biosynthesis of a composition, comprising the following steps:

- (a) providing a tubule or nanotubule, bundle, ball, fiber, filament or sheet comprising a plurality of enzymes comprising a biosynthetic pathway as set forth in claim 27;
- (b) providing a substrate for at least one enzyme; and,
- (c) contacting the tubule or nanotubule, bundle, ball, fiber, filament or sheet with the substrate under conditions wherein the enzymes of the biosynthetic pathway catalyze the synthesis of the composition.

44. The method of claim 43, wherein the enzymes are expressed in the inner lumen of the tubule or nanotubule, bundle, ball, fiber, filament or sheet.

45. The method of claim 43, wherein the enzymes are expressed on the exterior of the tubule or nanotubule, bundle, ball, fiber, filament or sheet.

46. A cell comprising a chimeric protein of claim 1 or a tubule or a nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

47. The cell of claim 46, wherein the cell is a bacterial cell, a plant cell, a yeast cell, a fungal cell, an insect cell or a mammalian cell.

48. A transgenic non-human animal comprising a chimeric protein of claim 1 or a tubule or a nanotubule as set forth in claim 27.

49. A plant or a seed comprising a chimeric protein of claim 1 or a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

50. A fiber comprising a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

51. A fabric or textile comprising a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

52. A fabric, textile, sheet or covering comprising a fiber or a thread comprising a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27, wherein the tubule or nanotubule, bundle, ball, fiber, filament or sheet is woven into a fabric, textile, sheet or covering.

53. A product of manufacture comprising a chimeric protein of claim 1 or a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27, a non-derivatized cannulae protein, or a combination thereof.

54. The product of manufacture of claim 53 comprising a computer, a transistor or a circuit comprising the chimeric protein.

55. The product of manufacture of claim 53 comprising a sheeting, a covering, a coating or an adhesive comprising the chimeric protein.

56. The product of manufacture of claim 53 comprising a flame retardant or heat resistant device comprising a sheeting, a covering, a coating or an adhesive comprising the chimeric protein.

57. A medical device or an implant comprising a chimeric protein of claim 1 or a tubule or a bundle or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27, a non-derivatized cannulae protein, or a combination thereof.

58. A method for polymerizing a nanotubule, bundle, filament or sheet comprising mixing a plurality of chimeric proteins as set forth in claim 1 in a solution comprising an iron sulfate, a manganese sulfate, a lead sulfate, a lithium sulfate, a manganese chloride or a calcium chloride or an equivalent salt, under conditions wherein the chimeric protein polymerizes into a nanotubule.

59. A fluorescent chimeric polypeptide comprising at least a first domain comprising a cannulae polypeptide and a second domain comprising a heterologous polypeptide or peptide, wherein the heterologous polypeptide or peptide comprises a fluorescent moiety.

60. The fluorescent chimeric polypeptide of claim 59, wherein the fluorescent moiety comprises a green fluorescent protein or equivalent.

61. A fluorescent nanotubule, bundle, filament or sheet comprising a fluorescent chimeric polypeptide of claim 60.

62. A bonding or adhesive composition comprising a microarray, filament, sheet, fabric or bundle comprising a plurality of chimeric proteins as set forth in claim 1.

63. A bonding or adhesive composition comprising a microarray, filament, sheet, fabric or bundle comprising a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

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64. A filter comprising a microarray, filament, sheet, fabric or bundle comprising a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

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65. A detecting device comprising a microarray, filament, sheet, fabric or bundle comprising a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

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66. A detoxifying device comprising a microarray, filament, sheet, fabric or bundle comprising a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

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67. A kit comprising a product of manufacture comprising a chimeric protein as set forth in claim 1 or a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27, a non-derivatized cannulae protein, or a combination thereof, and instructions for using the product of manufacture.

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68. A pharmaceutical composition comprising a chimeric polypeptide as set forth in claim 1 or a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27.

69. A pharmaceutical composition comprising a chimeric polypeptide comprising at least a first domain comprising a cannulae polypeptide and at least a second domain comprising a heterologous domain.

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70. The pharmaceutical composition of claim 68 or claim 69, wherein the heterologous domain is attached at the amino terminal end, the carboxy terminal end or internal to the cannulae polypeptide.

71. The pharmaceutical composition of claim 68 or claim 69, wherein the cannulae polypeptide comprises a protein having at least about 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% sequence identity to SEQ ID NO:2, SEQ ID NO:4, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10 or SEQ ID NO:12, or a FtsZ protein domain.

72. The pharmaceutical composition of claim 68 or claim 69, wherein the chimeric polypeptide comprises a recombinant fusion protein and the heterologous domain comprises polypeptide or a peptide.

73. The pharmaceutical composition of claim 68 or claim 69, wherein the heterologous domain of the chimeric polypeptide comprises an epitope, an immunogen, a toleragen, a carbohydrate binding domain, a cell matrix binding domain, a small molecule, a small molecule binding domain, a lipid, a carbohydrate, an enzyme, a cytokine or an antibody.

74. A vaccine comprising a chimeric polypeptide as set forth in claim 1 or a tubule or nanotubule, bundle, ball, fiber, filament or sheet as set forth in claim 27, and a pharmaceutically acceptable excipient.

75. The vaccine of claim 74, wherein the heterologous polypeptide or peptide of the chimeric polypeptide comprises an epitope, an immunogen, a toleragen, an immunomodulatory agent, an immune suppression agent, an adjuvant, an antibody, a cell binding agent, a carbohydrate or a combination thereof.

76. The vaccine of claim 74, wherein the chimeric polypeptide is assembled or self-assembles into a tubule or nanotubule, bundle, ball, fiber, filament or sheet.

77. A method for modulating the immune system of an individual comprising administering a pharmaceutically effective amount of a composition as set

forth in claim 1, a pharmaceutical composition of claim 68 or claim 69 or a vaccine as set forth in claim 74.

5 78. The method of claim 77, wherein a humoral or a cell-based immune response is elicited in the individual.

 79. The method of claim 77, wherein the individual is a human.

10 80. A carbohydrate-based therapeutic pharmaceutical composition comprising a composition as set forth in claim 1, or a tubule or nanotubule, bundle, ball, fiber, filament, thread, or sheet as set forth in claim 27, wherein the composition, tubule or nanotubule, bundle, ball, fiber, filament, thread, or sheet comprises at least one carbohydrate.

15 81. The carbohydrate-based therapeutic pharmaceutical composition of claim 80, wherein the composition, tubule or nanotubule, bundle, ball, fiber, filament, thread, or sheet comprises a polypeptide or peptide having a carbohydrate-binding motif.

20 82. The carbohydrate-based therapeutic pharmaceutical composition of claim 81, wherein the carbohydrate-binding motif is an N-linked carbohydrate-binding motif or an O-linked carbohydrate-binding motif.

25 83. The carbohydrate-based therapeutic pharmaceutical composition of claim 80, wherein the carbohydrate is added chemically, by cellular biosynthetic mechanisms, by *in vitro* enzymatic reactions, or a combination thereof.

 84. A method for ameliorating a disease or condition comprising administering a pharmaceutically effective amount of a carbohydrate-based therapeutic pharmaceutical composition of claim 80 to an individual.

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 85. The method of claim 84, wherein ameliorating the disease or condition comprises inhibition of carbohydrate-lectin interactions; immunization with carbohydrate antigens; inhibition of enzymes that synthesize disease-associated carbohydrates; inhibition of carbohydrate-processing enzymes; targeting of drugs to

specific disease cells via carbohydrate–lectin interactions; administering carbohydrate based anti-thrombotic agents.

5 86. A cell matrix binding composition comprising a composition as set forth in claim 1, or a tubule or nanotubule, bundle, ball, fiber, filament, thread, or sheet as set forth in claim 27, wherein the composition, tubule or nanotubule, bundle, ball, fiber, filament, thread, or sheet comprises at least one a cell matrix binding motif.

10 87. The cell matrix binding composition of claim 86, wherein the cell matrix binding motif comprises an RGD-binding motif or an RGD motif.

 88. The cell matrix binding composition of claim 86, comprising a medical device.

15 89. The cell matrix binding composition of claim 88, wherein the medical device comprises a dental or orthopedic prostheses, a dental device or implant, an orthopedic device, a pin, a screw, a fixture, a plate, a stent, a stent sheath, a shunt, a catheter, a valve, a cannulae, a tissue scaffold, a wound care device, a dressing or a lens.

20 90. A tissue scaffold or implant material comprising a composition as set forth in claim 1, or a tubule or nanotubule, bundle, ball, fiber, filament, thread, or sheet as set forth in claim 27.

25 91. The tissue scaffold or implant material of claim 90, wherein the tissue scaffold comprises a polymer scaffold and neural stem cells for repairing a spinal cord injury.

30 92. The tissue scaffold or implant material of claim 90, wherein the tissue scaffold comprises a vascular graft comprising graft material from smooth muscle, endothelial muscle and/or stem cells.

 93. A cell or tissue transplant device or a cell or tissue implant device comprising a composition as set forth in claim 1, or a tubule or nanotubule, bundle, ball, fiber, filament, thread, or sheet as set forth in claim 27.

94. The cell or tissue transplant device or a cell or tissue implant device of claim 93, wherein the cells or tissues comprise nerve cells or tissues, skin cells or tissues, epidermal cells, dermal cells, liver cells or tissue; kidney cells or tissue;
5 pancreatic cells or tissues; tubular structural cells, vascular elements, arteries, arterioles, veins, ureter cells or structure, bladder cells, urethral or structure, ductal tissue, bone cells or tissue, cartilage cells and/or muscle cells or tissue.

95. The chimeric polypeptide of claim 1, wherein the cannulae
10 polypeptide comprises a FtsZ domain.

96. A bottle-brush polymeric protein structure comprising a chimeric polypeptide of claim 1 and a FtsZ domain.

97. A chromatography resin comprising a chimeric polypeptide of
15 claim 1.

98. A chromatography resin comprising a chimeric polypeptide of
claim 1 and a FtsZ domain.

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